

NEW FIBRES FOR THE TEXTILE INDUSTRY OF THE XXI CENTURY. CHARACTERISTICS AND FINAL APPLICATIONS.

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Summary:

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- 2. Fibrous materials and textile fibres.**
- 3. To day. - The most common man made fibres.**
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1. ABSTRACT - INTRODUCTION.

Innovation is today the main commitment for the future of the textile industry. New products are constantly searched, and new generation fibres are a class of products of remarkable importance in the development of innovative textile products.

Most of the new fibres introduced in the market in the past decade are an evolution and a modification of existent polymers and fibres, but others, as for instance PLA fibre and PTT fibre in the family of synthetic fibres and soy fibre and bamboo fibre in the family of artificial fibres, are completely new.

Developing and manufacturing these kinds of products, both in fibre manufacturing and in the whole textile process, is surely more complex and expensive than processing conventional fibres, but they give at the final application, high added value.

This paper will explain the main difference between the different families of new fibres introduced in the market in the past few years and their main textile application.

Mainly:

Chemical and physical intrinsic characteristics of the new fibres.

Basic concepts how these products have to be processed in spinning, weaving and finishing.

Requirements of the final applications: examples in basic products for standard textile products and industrial end uses.

2. FIBROUS MATERIALS AND TEXTILE FIBRES.

2.1. Fibrous materials.

Fibre:

A fine thread or thread-like cell of a natural or artificial substance.

Textile fibre:

Any fibrous material which can be used to manufacture textile products.

- Staple fibre. > short fibre that having textile product have to be: spun and twist in a yarn. bond in a non woven textile.
- Continuous filament. > long filaments that are already a textile product.

2.2. The fibers made by the man. - The invention of man made fibers.

2.2.1. Fibers from natural polymers. Artificial fibers.

2.2.1.1. Cellulose fibres.

Rayon: (100% regenerate cellulose)

1892, Nitrocellulose process, Hilaire de Chardoney – lost – too expensive and dangerous.

1925, Viscose process – Courthaulds, U.K. starts the sales of the first viscose staple fiber: "Fibro".

Rayon cuprammonium (100% regenerate cellulose)

1892, First industrial developments in Germany – poor commercial results.

1920/1930, J.P. Bemberg improves the industrial process and starts the sales of filament yarns.

Rayon acetate (cellulose diacetate e triacetate) :

1921, Celanese develops the industrial process and starts the sales of filament yarns.

Rayon, viscose, cuprammonium and acetate, are still produced with advanced and environment friendly production process.

They have small but important niches of market

2.2.1.2. Protein fibres.

Casein fibre (milk protein).

1935, Snia Viscosa, starts the sales of Lanital, later improved and brand Merinova.

1938, Courthaulds starts the sales of a fibre similar to Lanital, brand Fibrolane.

Others protein fibre developed from 1935 to 1945:

U.K., Ardil from adreine. (peanut).

USA, Vicara from zeine (corn).

Japan, ???? No brand (soy).

Protein fibres, created to imitate wool, really disappear from the market in '60 decade with the introduction in the market of more performance synthetic fibres', mainly acrylic fibres.

Recent developments:

Few years ago was introduced in the market a new protein fibre, SPB, from soy, as wool and cachemir imitation.

China, Xinhui Yuexin Chemical Fibre Co., Ltd. (soy).

2.2.2. Fibers from polymers. not present in nature - Synthetic fibers.

Polyvinylchloride.

1913, F. Klatte, of the Griesheim-Elektro, realized in Germany the first synthetic fiber, departing from a chlorinated polymer.

The productive difficulties, particularly the recovery of the solvent of spinning, (cicloesanol), prevented him to develop it in industrial way

1931, R. Hupert, of the I. G. Farbenindustrie, on the base of the studies and the experiences of other two German researchers C. Schoenburg and W. Reppe, realized PeCe, chlorinated fiber, introduced on the market in 1934. PeCe was the first synthetic fiber industrially made, but for the superior technological characteristic, it is the nylon, made few years later, to be considered "the first true synthetic fiber"

Polyamide.

1931, W.H. Carothers, researcher of the Du Pont de Nemours announces to American Chemical Society to have realized, departing from adipic acid and esamitilendiammine, a new polymer denominated "nylon", and to have produced "a handful of fiber, which, are showing a resiliency similar to the wool. The elastic qualities of these fibers are very superior to any artificial note silk."

The first one "nylon" begins to be produced industrially in 1937 and it appears on the market in 1939.

Since it is gotten departing from an acid and from an ammine, having both 6 atoms of carbon, it is known how nylon 66.

1937, P.Schlack, of the I.G. Farbenindustrie, was able to polymer caprolactam, creating a fiber called “Perlon.”

Perlon has been produced industrially since 1943, and is known as Nylon 6. (6 atoms of carbon).

3. TO DAY - THE MOST COMMON MAN MADE FIBRES.

3.1. Polyester.

1941 Developed in U.K. by J. R. Whinfield and J. T. Dickson departing from studies of Carothers.

1948 Start of the experimental production on plant pilot. The patents, expired at the beginnings of '70, years.

They were acquired by Du Pont, for America, fiber “Dacron” and from ICI for the rest of the world fiber “Terylene”.

3.2. Polyacrylic.

1940 The date is not sure because of the war in progress. The first experimental productions in Germany, by of H. Rhein and in USA, by G. H. Latham and R. C. Houtz.

1948 Du Pont USA patents the fiber “Orlon” and in 1950 begins the marketing of it.

3.3. Polypropylene.

1954 Prof. G. Natta in the laboratories Montecatini, develops the isotactic polypropylene. From that invention derived before the plastic material Moplen followed by the first PP fiber, the Meraklon. For this invention prof. Natta will win two years later, the Nobel prize for the chemistry.

3.4. Other man made fibre for especial end uses.

3.4.1 - Flame retardant fibres.

They are mainly produced by three families of basic polymers:

- From natural modified polymers
 - > cellulose – viscose CV - LOI 20 > viscose fr CV - LOI 26/28 (Lenzing FR ®), Visil ®)
- From synthetic modified polymers
 - > polyester PET – PES - LOI 19/21 > polyester fr PET – PES - LOI 28/30 (Trevira cs ®, Securelle ®)
 - > acrylic PAN - LOI 19/21 > modacrylic fr MAC - LOI 28/34 (Kanekaron ®, Protex®)
- From intrinsically flame retardant polymers. clorofibre CLF - LOI 38/46 (Rhovil ®)

3.4.2 - Bioactive (antibacterial) fibres.

They are mainly produced by two families of basic polymers:

- From natural modified polymers
> cellulose – modal > bioactive modal
(Modal Fresh ®)
- From synthetic modified polymers
> polyester PET – > bioactive polyester
(Trevira bioactive ®)
> acrylic PAN > bioactive acrylic
(Amicor - Amicor Plus ®)

3.4.3. - High tech or/and high performance fibres.

3.4.3.1 Organic origin.

They are only produced by engineered synthetic polymers.

The most important, on the market point of view are:

Aramid.

Para-aramid (polyparaphenylene terephthalamide) PPTA . (LOI 27/29).
(Kevlar®, Twaron®.)

Para-aramid (copolymer, polyparaphenylene/3,4'-oxidiphenylene terephthalamide)
PPTAC. (LOI 25)
(Technora®.)

Meta-aramid (polymetaphenylene isophthalamide) PMIA. (LOI 29/32)
(Nomex®, TeijinConex®.)

Meta-aramid (polyamide imide) PAI. (LOI 32)
(Kermel®.)

Meta-aramid (copolyimide) PIC. (LOI 36)
(P.84)

Fluoropolymer. (polytetrafluoroethylene) PTFE (LOI >90)
(Teflon®, Profilen®.)

Melamine. (melamine formaldehyde resin) MF (LOI 32)
(Basofil®)

Phenolic. (phenol-aldehyde resin) PHE (LOI 30/34)
(Kynol®)

Polybenzimidazole. (polybenzimidazole) PBI (LOI 41).
(Celanese PBI®)

PBO fiber. Poly-phenylene-2,6benzobisoxazole PBO (LOI 68)
(Zylon®)

Phenylene Sulphide. Poly-phenylene sulphide PPS (LOI 34)
(Procon®) (Torcon®,.

Inorganic origin .

- Carbon fibre. > 99,9% carbon CF
- Metallic fibre. 100% stainless steel, 100% silver, 100% copper. MTF
- Glass. GF - Boron. B - Silicon carbide. SiC – Silica Sil.

4. -MAN MADE FIBRES. PRODUCTION TECHNOLOGY.

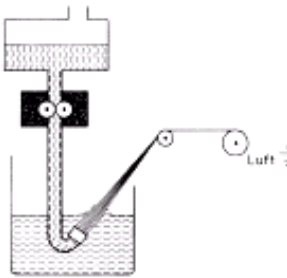
The chemical fibers, both artificial and synthetic, are produced, excepted particular exceptions, departing from a polymer turned into a semi melt mass (DOPE), through solution or fusion, and extruded through a spinneret with more holes, and sequential solidification of the spun filaments.

Filaments are then oriented at molecular level, with drawing process and fix.

The technologies used in “primary spinning” are essentially three:

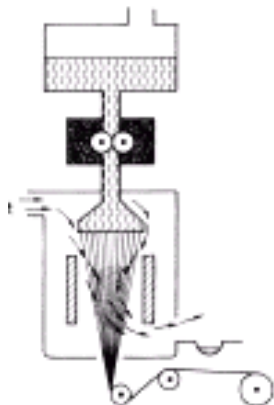
4.1. Wet spinning.

The polymer is dissolved in proper solvent, extruded and the filaments are coagulated in watery environment. This technology was the first to be developed and it is today still used for producing the rayons both continuous filaments and staple fibers, the most part of the acrylic fibers, the modacrylic fibers, and the aramid fibers.



4.2. Dry spinning with solvents.

The polymer is dissolved in a proper solvent and extruded in warm air, at a temperature such to allow the solvent evaporation and the contemporary consolidation of the filaments. This technology is used for acetate, some acrylic and polyvinylchloride

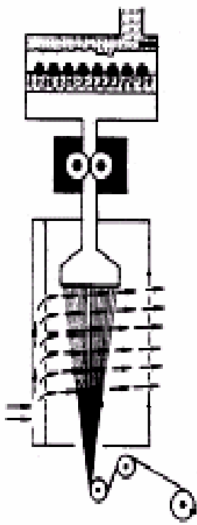


4.3. Dry spinning by fusion.

The polymer is fused, extruded, and filaments are solidified for cooling with forced air in a chimney called “quench”.

It is the most economic and productive technology. It allows high speeds of extrusion and it doesn't need any washing of the filaments after solidification. It is proper only with polymers that reach the temperatures of fusion without decomposing themselves and that have, in fusion and extrusion low variations of viscosity.

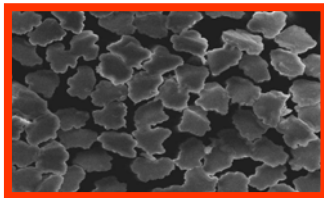
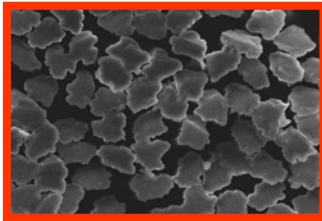
It is used for polyamides, polyester, polypropylene, phenol/polyphenylsulphide > PPS.



WET SPUN FIBRES.

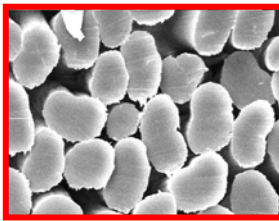
**ARTIFICIAL
FIBRES.**

Cellulose Viscose



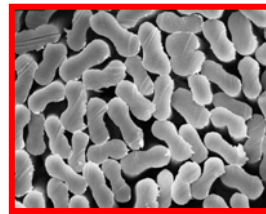
**SYNTHETIC
FIBRES.**

Acrylic



**DRY SOLVENT
TECHNOLOGY.**

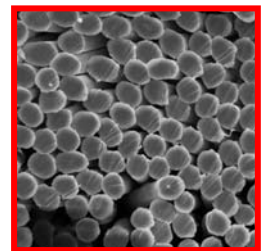
**SYNTHETIC
FIBRES.**
Acrylic
Aramide



**DRY FUSION
TECHNOLOGY.**

**SYNTHETIC
FIBRES.**

Polyamides
Polyester,
Polypropylene,



4.4. - To day we have a quite new spinning technology: "Electro spinning".

Electro spinning can be considered a "retrofit and upgrade" of the three traditional technologies seen at the previous chapter. Fibers are extruded using a traditional technology, and oriented at molecular level using "Electro spinning".

In the last years different techniques have been tried to produce single nanofibre and continuous filament, but electrospinning is surely the only one to day available.

The prefix "nano", a Greek word meaning "dwarf", denotes a one billionth part (10^{-9}m) that is, about 1/80,000 of the diameter of a human hair.

In 1934, a process was patented by Formhals.

An experimental setup was outlined for the production of polymer filaments using electrostatic force. When used to spin fibres this way, the process is termed as electrospinning.

This is a summary of the Formhals experiments description:

"In the electrospinning process a high voltage is used to create an electrically charged jet of polymer solution or melt, which dries or solidifies to leave a polymer fibre . One electrode is placed into the spinning solution/melt and the other attached to a collector. Electric field is subjected to the end of a capillary tube that contains the polymer fluid held by its surface tension. This induces a charge on the surface of the liquid. Mutual charge repulsion causes a force directly opposite to the surface tension. As the intensity of the electric field is increased, the hemispherical surface of the fluid at the tip of the capillary tube elongates to form a conical shape known as the Taylor cone. With increasing field, a critical value is attained when the repulsive electrostatic force overcomes the surface tension and a charged jet of fluid is ejected from the tip of the Taylor cone. The discharged polymer solution jet undergoes a whipping process wherein the solvent evaporates, leaving behind a charged polymer fibre, which lays itself randomly on a grounded collecting metal screen. In the case of the melt the discharged jet solidifies when it travels in the air and is collected on the grounded metal screen.

Apparatus: An example of one experimental set up used for electrospinning is shown in Fig. 1

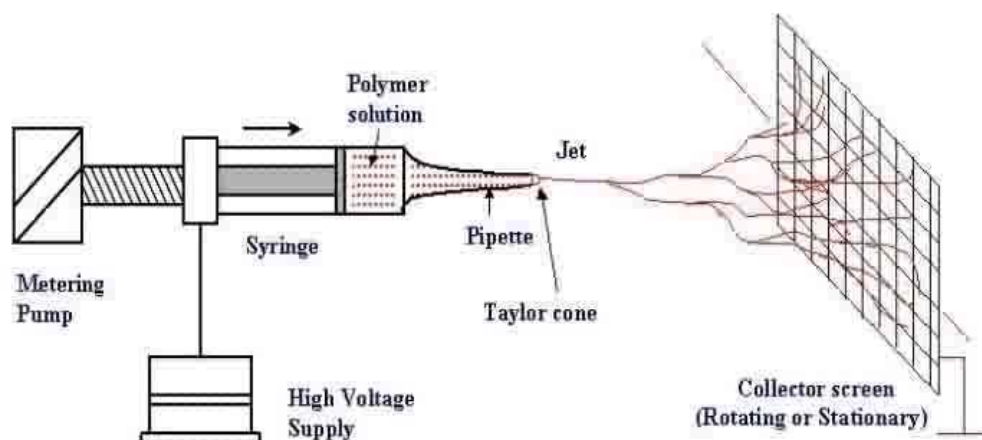


Figure 1. Schematic of the Electrospinning setup.

"The polymer solution or melt is contained in a glass tube, usually a pipette that is connected to a syringe like apparatus. A metering pump attached to the plunger of the syringe generates a constant pressure and flow of the fluid through the pipette. The driving force is provided by a high voltage source through a wire immersed in the solution. The high voltage source can generate up to 30 kV, and the setup can be run on either positive or negative polarity. Adjusting the flow of the fluid and the magnitude of the electric field controls the spinning rate."

Abstract from:

Formhals, A., US Patent, 1,975,504 (1934), Formhals, A., US Patent, 2,160,962 (1939), Formhals, A., US Patent, 2,187,306 (1940), Doshi, J & Reneker, D.H., J. of Electrostat., 35, 151 (1995), Engineering Fiber System, 1995.

5. - RECENT AND NEW FIBRES.

We can have a new fibre from:

5.1 . - New fibre by change of physical-mechanics characteristics of an existing fibre.

Developing time: short/medium, for 6 months to 1 years

Example:

Special cross section fibres, hollow fibres, multilobal fibres

Low or high modulus fibres.

Cationic dyeable fibres.

5.2. - New fibre from different existing polymers conjugated.

Developing time: medium, for 1 to 5 years

Example:

Low melting core fibres. Anti-static fibres (some).

5.3. A modification of existing polymer:

Developing time: medium, for 1 to 5 years

Investments: medium/high.

Example:

Flame retardant fibres: Polyester fr., Modacrylic fr.

Bioactive fibres: Polyester bioactive, Acrylic bioactive.

5.4. A new process for existing polymer/molecule.

Developing time: long, for 3 to 8 years

Investments: very high.

Example:

Lyocell fibres. 100% cellulose fibre solvent spun.

Commercial brand name: Lenzing > Tencel

5.5. A new polymer - new molecule.

Developing time: long, for 5 to 10 years

Investments: very high.

Examples:

PTT. Polythreemethilenterefphtalate

Commercial brand names: Shell Chemical > Corterra

Du Pont > Sorona

PLA. Polylactide.

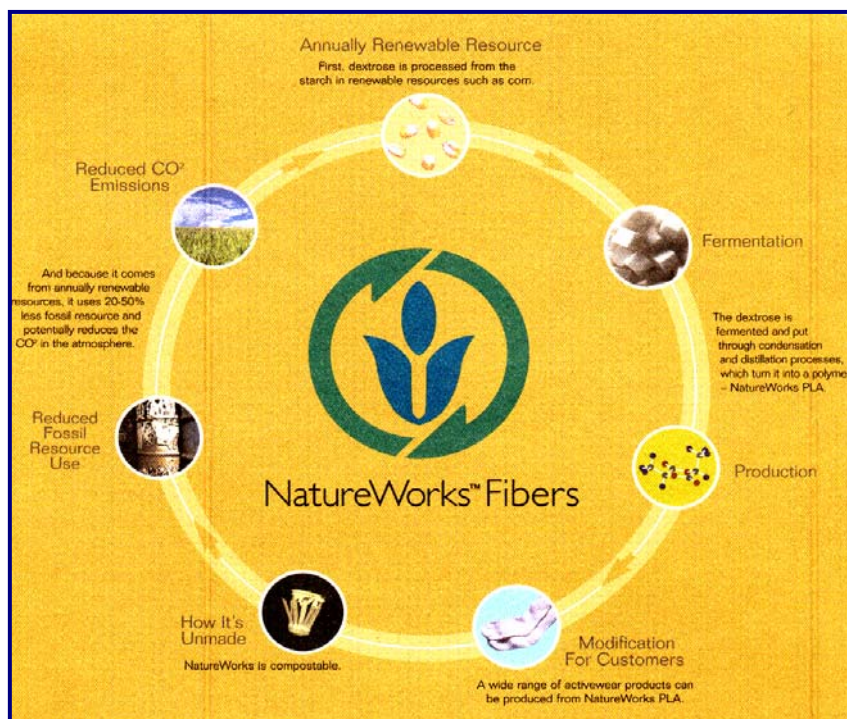
Commercial brand name: Cargill Dow > Ingeo

5.5.1. - New fiber from a new molecule.

PLA is a new polymer, developed by Cargill Dow, with the brand name NatureWorks®.

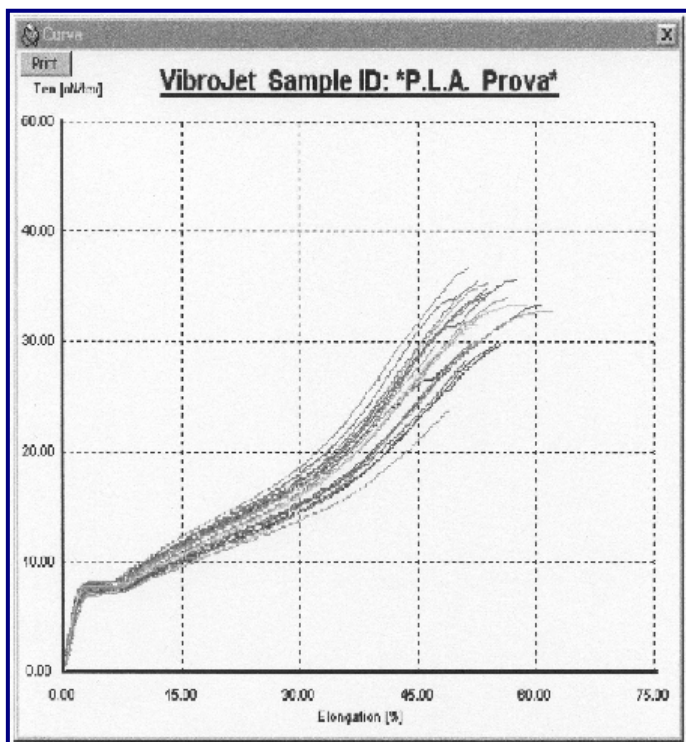
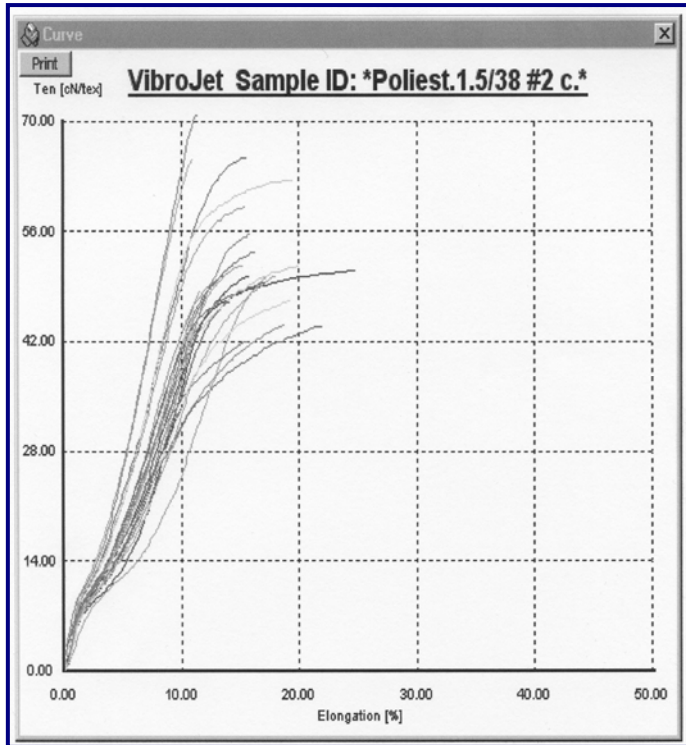
The raw material for PLA is dextrose, got out by agricultural primary products, as corn. Cargill Dow manufacturing process, first, converts dextrose into lactic acid, using a fermentation technology, second, by condensation, transform the lactic acid in the basic monomer, "lactide".

PLA is made by a ring-opening polymerisation of "lactide".



PES fibre dtex 1,5, versus PLA fibre dtex 1,5.

Physical and mechanics characteristics comparison.



6. FINAL APPLICATIONS.

FAMILY	TEXTILE TECHNOLOGY	A	B	C	D
		FILAMENT	STAPLE FIBRE	MAIN FINAL END USE	OTHER END USES
Artificial cellulose fibres					
Viscose and modal	traditional textile	weaving, circular knitting	spinning, weaving, circular knitting	fashion fabrics and knits - lining.	medical tyres cords filtration
	direct use, non woven textiles		needle bond, spun lace	disposable	
Lyocell	traditional textile	NO FILAMENT	spinning, weaving, circular knitting	fashion fabrics and knits - lining.	tyres cords
	direct use, non woven textiles		needle bond, spun lace	disposable	filtration
Most used synthetic fibres					
Polyester	traditional textile	weaving, circular knitting, warp knitting	spinning, pure and blend weaving, circular knitting	curtains, fashion fabrics and knits - lining.	technical, industrial tyres cords filtration
	direct use, non woven textiles		spun bonded, needle bond, spun lace	technical, industrial	
Polyamide	traditional textile	weaving, circular knitting, warp knitting	spinning, pure and blend weaving, circular knitting	socks, fashion fabrics and knits - lining. protective clothing backing for coating	tyres cords technical, industrial filtration
	direct use, non woven textiles		spun bonded, needle bond		
Polypropylene	traditional textile	weaving, circular knitting, warp knitting	spinning, pure and blend weaving, circular knitting	technical, industrial	tyres cords sport socks, mattresses. filtration
	direct use, non woven textiles		spun bonded, needle bond	technical, industrial	
Acrylic	traditional textile	NO FILAMENT	spinning, pure and blend weaving, circular knitting	flat knitting, circular knitting, warp knitting weaving	technical - sun tents, boat covering
Flame retardant fibres - Artificial cellulose fibres					
Viscose fr	traditional textile	NO FILAMENT	spinning, pure and blend weaving, circular knitting	protective clothing	curtains, upholstery fabrics.
				technical, industrial	
Flame retardant fibres - Synthetic fibres					
Polyester fr	traditional textile	weaving, circular knitting	spinning, only pure weaving, circular knitting	curtains, upholstery fabrics.	technical, industrial
	direct use, non woven textiles			technical, industrial	
Modacrylic fr	traditional textile	NO FILAMENT	spinning, pure and blend flat knitting, circular knitting, warp knitting	curtains, upholstery fabrics.	technical, industrial, protective clothing filtration
Bioactive (antibacterial) fibres					
All the fibres	traditional textile	weaving, circular knitting	spinning, mainly blend weaving, circular knitting	uniforms, socks, mattresses,	technical, industrial
	direct use, non woven textiles			technical, industrial	
High tech or/and high performance fibres					
All the fibres	traditional textile	weaving, circular knitting	spinning, pure and blend weaving, circular knitting	protective clothing, filtration	technical, industrial
	direct use, non woven textiles			filtration	technical, industrial

7 . SHORT AND MEDIUM/LONG TERMS FORECAT - CONCLUSIONS.

The development of a completely new fibre requires, as seen in precedence, very long time and huge investments to reach the phase of industrial production. Dow Cargil, to develop PLA Ingeo, has spent from the phase of study, to the realization of the first industrial plant for the production of the polymer about 200 Mils. of US \$. All the short time and low investment projects are therefore addressed to further changes and upgrading of the existing fibres.

The few long time term projects , already in progress, are mainly aimed to develop new polymers and new fibres departing from renewable raw materials of vegetable origin.

Not only Ingeo, also but also Sorona is a synthetic fibre, but from vegetable origin. We have to take note that Du Pont sold all the fibres business, but not Sorona, that is still Du Pont.

The vegetable raw materials usable can be diversify a lot, but actually the more used is corn, for its high availability to world level. A Chinese producer has been introduced on the market about two years ago a fibre drawn by the seed of soy, but its diffusion is very limited.

Nanofibres have to today three big problems to reach a short terms industrialization:

1. The technology today used, electrostatic spinning, is still at level of laboratory apparatus, and it needs high investment in research and engineering to project and realise an industrial plant.
2. The polymers till to day experimented, only at laboratory level, are very limited, mainly polyester.
3. There is not a market ready to receive this new typology of products. Perhaps some sector of niche as the micro-filtration for the sanitary and medical sector would be able to begin a semi industrial experimentation today.

Surely not the traditional textile sector, also the most advanced, in which also the simple "super-microfibre" type island on the sea, that are on the market from at least 15 years, have a limited market. Are used only for very expensive and real niche products, as Alcantara and similar products.

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